The results for the atomic weight of tin are arranged in the order in which the fractions were distilled, not in the order of analysis. Since only slight irregular variations are apparent, there can be little question that the different portions were identical in composition.

The final average, Sn = 118.703 (Cl = 35.457) is in very close agreement with the one obtained by Briscoe by comparison with silver, 118.698. The percent of tin in stannic chloride found by us is 45.562, while Briscoe found 54.439% of chlorine. The sum is 100.001%, a highly satisfactory and convincing outcome.

It is a great pleasure to express our gratitude to the Carnegie Institution of Washington and to the Elizabeth Thompson Science Fund for very generous assistance in providing indispensable apparatus.

[1] *Trans. Chem. Soc.*, 107, 63 (1915).

[2] *Ber. D. Chem. Ges.*, 21, 2900 (1888).

[3] Baxter and Hartmann, *J. Amer. Chem. Soc.*, 37, 113 (1915). Baxter and Grose, *Ibid.*, 38, 857, 868 (1916).

[4] Baxter and Hartmann, these PROCEEDINGS, 1, 26 (1915).

FURTHER STUDIES OF NERVE CONDUCTION IN CASSIOPEA

By Alfred Goldsborough Mayer

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Studies of recent years have shown the importance of hydrogen ion concentration in determining the rate of nerve conduction in *Cassiopea*. Ordinary distilled water often remains acid even though air freed from CO_2 by means of soda-lime has been bubbled through it for 72 hours. Accordingly, Prof. George A. Hulett kindly arranged to have 144 litres of distilled water prepared in accordance with his well known method (Ueber die Reinigung des Wassers durch Distillation, *Zs. phys. Chem.*, 21, 287, 1896) in his laboratory at Princeton University. This water was sealed in 144 pyrex glass flasks and thus transported to Tortugas. The hydrogen ion concentration of each flask was tested separately, the range being 0.8 to 1.0×10^{-6}, and the average being 0.9×10^{-6}, or 6.04 PH.

Fifty litres of this water were placed in a green glass carboy which had previously held Merck's distilled water; and air freed from CO_2 was bubbled through it at an active rate for 78 hours, after which the water in the carboy had a PH. of 8.0 which it maintained for eight days while 139 experiments were made with it. The alkalinity then declined to 7.5 PH. while 26 other experiments were made; the average for the

series being 7.93 PH. or 1.17 $\times$ 10^{-8} hydrogen ion concentration. Its alkalinity was probably due to soda derived from the glass carboy, the balance being maintained by a tendency of the water itself to become acid through leakage of CO_2 from the air. Professor J. F. McClendon found the PH. of the Tortugas sea water to range from 8.1 to 8.22, and dilution with alkaline distilled water of 7.93 PH. maintained the normal hydrogen ion concentration of the sea water even when diluted with its own volume of such distilled water.
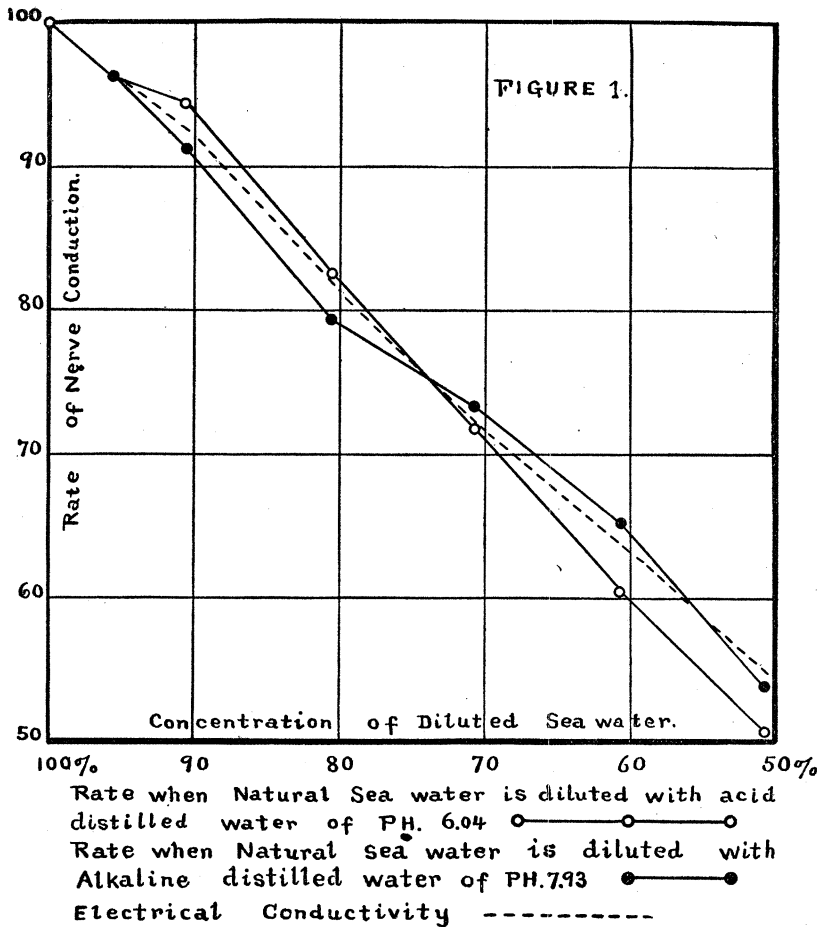
TABLE I

ILLUSTRATED BY FIGURE 1

COMPOSITION OF THE SOLUTION	I RATE OF NERVE CONDUCTION WHEN THE SEA WATER IS DILUTED WITH ACID DISTILLED WATER OF 6.04 PH. AT 30°C.	PROBA-BLE ERROR	II RATE OF NERVE CONDUCTION WHEN THE SEA WATER IS DILUTED WITH ALKALINE DISTILLED WATER OF 7.93 PH AT 30°C.	PROBA-BLE ERROR	III RELATIVE ELECTRICAL CONDUCTIVITY OF TORTUGAS SEA WATER DILUTED WITH DISTILLED WATER OF 7.8 PH. AT 30°C.
Natural sea water of 8.1 to 8.22 PH..........................	100.00		100.00		100.00
95 cc. sea water + 5 cc. distilled water......................	96.43	0.74	96.23	0.67	
90 cc. sea water + 10 cc. distilled water......................	94.38	0.88	91.44	1.00	92.16
80 cc. sea water + 20 cc. distilled water......................	82.68	1.16	79.51	1.18	81.38
70 cc. sea water + 30 cc. distilled water......................	71.95	1.13	73.91	1.16	71.53
60 cc. sea water + 40 cc. distilled water......................	60.41	0.59	65.72	1.01	64.26
50 cc. sea water + 50 cc. distilled water......................	50.83	0.90	54.16	0.79	54.08

It will be seen by comparing columns II and III of the above table that when alkaline distilled water of about 8 PH. is used to dilute the sea water the decline in rate of nerve conduction is practically the same as the decline in the electrical conductivity of the sea water when similarly diluted. We should remember, however, that the concentration of the sodium, calcium and potassium cations declines in practically the same ratio and thus the rate of nerve conduction may be proportional to the concentration of these cations rather than to the electrical conductivity of the diluted sea water as a whole.

However, Prof. Ralph S. Lillie is right in a recent paper (*Amer. J. Physiol.*, **41**, 123) wherein he states his belief that the rate of nerve conduction in *Cassiopea* in diluted sea water does not decline in accord

with Freundlich's law of adsorption as I had erroneously supposed (these PROCEEDINGS, **1**, p. 270; **2**, p. 37).

The distilled water used in my previous experiments was slightly acid and thus stimulating in slight dilution and depressant in stronger dilutions (see Table I, column 1) thus giving the semblance of an adsorption curve. Nor did I realize the effects of slight changes in tem-

FIGURE 1.

Concentration of Diluted Sea water.

Rate when Natural Sea water is diluted with acid distilled water of PH. 6.04 ○————○————○

Rate when Natural Sea water is diluted with Alkaline distilled water of PH. 7.93 ●————●

Electrical Conductivity – – – – – – – – –

perature in the various solutions, for the effect of 0.1°C. is readily appreciable.

Lillie advocates an extension of the theory of Faraday and de la Rive, that the transmission of the excitation state from the immediate site of activity to the adjoining resting area is dependent on an electrical local action of the same essential nature as that which is responsible for the etching or corrosion of non-homogeneous metallic surfaces, such as iron

in contact with an electrolyte solution; and if this be true, the rate of nerve conduction should be a function of the electrical conductivity of the medium, and also of the surrounding fluid.

To further test this hypothesis, I determined the electrical conductivity of Tortugas sea water when heated or cooled, and compared it with the rate of nerve conduction at corresponding temperatures.

This shows that the rate of nerve conduction has a temperature coefficient about two and one-half times as high as that of the electrical conductivity of sea water; as will appear in Table II.
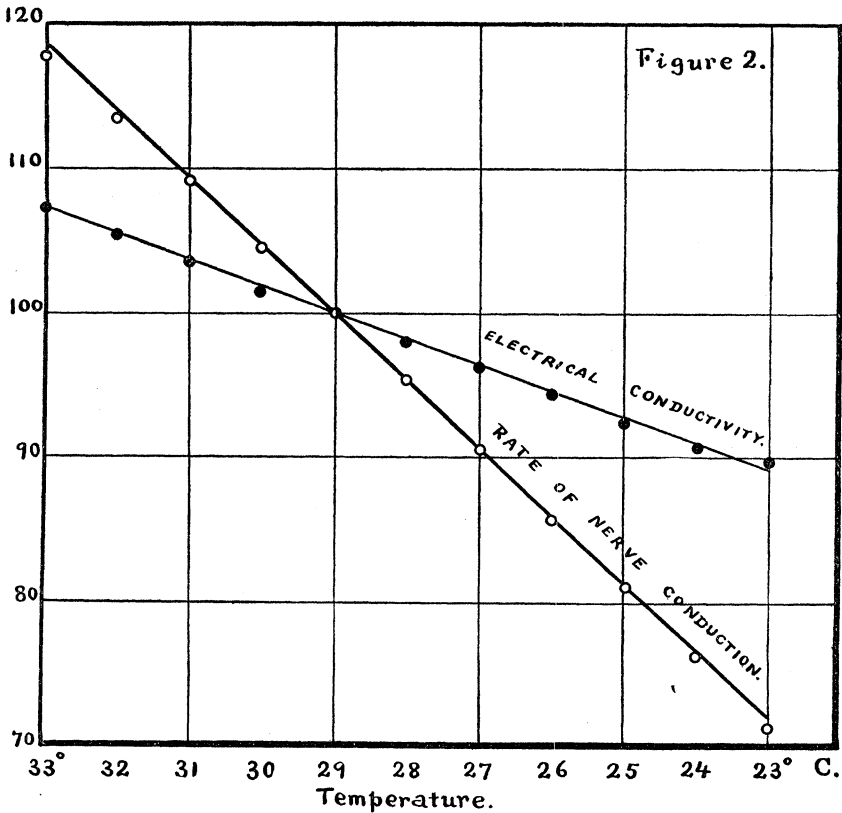
TABLE II

ILLUSTRATED BY FIGURE 2

TEMPERATURE C° OF THE SEA WATER	RATE OF NERVE CONDUCTION IN CASSIOPEA. MEAN OF HARVEY, MAYER, AND CARY'S OBSERVATIONS	RELATIVE ELECTRICAL CONDUCTIVITY OF TORTUGAS SEA WATER DETERMINED BY KOHLRAUSCH'S METHOD
23	71.3	88.9
24	76.3	90.7
25	81.17	92.6
26	85.8	94.4
27	90.74	96.2
28	95.47	98.0
29	100.00	100.0
30	104.47	101.6
31	109.2	103.5
32	113.4	105.3
33	117.8	107.1

It will be recalled that Harvey (1911, *Publ. Carnegie Inst. Washington*, No. 132) was the first to show that the rate of nerve conduction in *Cassiopea* augments in nearly a straight line as the sea water is heated until about 36° to 38°C. where it suddenly falls off, thus giving a curve resembling that of an enzyme reaction. This has been confirmed by the later work of Mayer, and Cary; and I find that when the rate has begun to fall off, the original rate is not recovered upon cooling. This may possibly mean that the hypothetical enzyme has been partially destroyed; for if this decline were due merely to asphyxiation the rate should recover to a greater degree when the medusa is replaced in sea water of normal temperature. Moreover, the high temperature coefficient of the rate of nerve conduction suggests that we may be dealing with a chemical reaction in which a compound is formed composed of sodium, calcium, and some proteid element; the degree of ionization of which is considerably affected by temperature in the manner suggested by Hardy, 1900; Quincke, 1902; and Bayliss, 1915, *Principles of General Physiology*, p. 77.

Possibly, also, the negative electrical potential associated with the wave of nerve conduction may increase the surface tension of the alkaline colloidal particles thus reducing their size, rendering them more soluble and thereby increasing the concentration of the reacting ions.

Contrary to Lillie's hypothesis, we have direct evidence that the rate of nerve conduction may be independent of the electrical conductivity of the solution surrounding the nerve, for I have found (these PROCEEDINGS, **1**, p. 270) that if sea water be diluted with 0.415 molec-

Figure 2.

ular $MgCl_2$ the rate of nerve conduction is only slightly more depressed than if the sea water is diluted with distilled water, or with dextrose; yet the $MgCl_2$ maintains a nearly normal electrical conductivity, while with distilled water or dextrose it declines in nearly the same ratio as the dilution. Nor do the experiments I have made with solutions containing some but not all the cations of sea water support Lillie's view. Thus if the rate of nerve conduction in 0.647 molecular NaCl is 55, it becomes 100 in 85.3 cc. of 0.6 molecular NaCl + 14.69 cc. of 0.39 molec-

ular MgCl₂. Here the electrical conductivity of the solution is somewhat reduced while the rate of nerve conduction is much augmented. This is, of course, a striking instance of Loeb's law of the antagonism between a univalent and a bivalent cation; even though the bivalent cation in this case is magnesium, well known to be a depressant especially for muscular activity in *Cassiopea*.

A full report will appear in papers from the Department of Marine Biology to be published by the Carnegie Institution of Washington.

THE EARLIEST FRESH-WATER ARTHROPODS

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In the year 1900 Prof. T. C. Chamberlin published a prophetic paper under the title *On the habitat of the early vertebrates.*[1] In this paper he holds that the problem which he is considering admits of no other than hypothetical treatment, and proposes the hypothesis that "The chordate phylum is . . . . essentially from first to last a terrestrial race, whose main habitat was the land waters and the land itself, though still a race that sent its offshoots down to sea from time to time from the mid-Paleozoic onwards " (412). He arrives mainly at this conclusion on the basis that the fish form among animals could only have originated through mechanical genesis in swift streams and under a mode of life independent of the bottom. The most essential mechanical feature of rivers is their flow in a fixed direction, and to this insistent physical condition animal life had to adapt itself, for "otherwise the animal would be swept out to sea and its race be ended as a stream-dweller. It is different with ocean currents, for they return upon themselves and an animal may yield to them without losing its marine habitat" (406). This hypothesis is applied mainly to the origin of the fishes and less insistently to the eurypterids.

In regard to the origin of the eurypterids Chamberlin states: "From the occurrence of eurypterids first in marine beds apparently and later in fresh-water deposits it has been inferred that they were originally sea-dwellers and later became adapted to land waters, but the meagerness of their marine record on the one hand, and their abundance and fine preservation in the fresh-water deposits on the other, give point to the question whether their early marine record is anything more than the chance deposit of river forms borne out to sea" (403). But "it may be equally true that the fish and the eurypterids descended